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1984

S. S. WAPAMA

RESTORATION

PROGRAM

JUNE 1, 1984

United States Department of the Interior
National Park Service
Golden Gate National Recreation Area

SS WAPAMA RESTORATION PROGRAM

SECTION I - GENERAL PROVISIONS

1.0 BACKGROUND

The SS Wapama is a timber vessel which was built on the West Coast for the coastal lumber trade. The construction site was St. Helens, Oregon and her completion date was 1915. Although the Wapama carries an ABS Load Line Disk, the first reference to the vessel in the ABS Register is to be found in the 1920 edition where she is shown to be unclassed. This means that the Wapama was not built under ABS supervision and guidance. Presently, the Wapama is the sole survivor of the fleet of coastal steam schooners which contributed so much to our nation's commerce. Because of the Wapama's distinction in her commercial activity and as the last of a kind, she has become historically significant.

Over the years where the vessel has been on display to the public, her timbers have been damaged by rot, weather and otherwise normal hull stresses which eventually take a toll of all vessels. The most noticeable weakness of the vessel was manifest in the 30-inch hog which the vessel developed. This hogging or "hump backed" condition indicated that the vessel's main structural members were significantly weakened to the point where her floating integrity was jeopardized. In order to relieve her main girders of this dangerous strain, the Wapama was landed upon a barge. This barge will provide the primary dry dock platform for her restoration.

2.0 HISTORICAL SIGNIFICANCE

Wooden shipbuilding on a scale of the Wapama has almost completely disappeared from the American repertory of skilled crafts. However, the legacy of that craft has given us the Wapama and the unique opportunity to study the vessel which has (somehow) survived all others.

Various specifications were set forth for the construction of timber vessels. Under the "Rules" presented by ABS and Lloyds, the Wapama represents a significant departure, as follows:

1. Steel strapping, or any other steel reinforcing, is not evident;

2. Edge fastenings in upper ceiling are not evident;

3. The Wapama utilizes sister frames within the bilge radius. The use of sister frames is not documented in the popular literature of the time, nor acknowledged by ABS.

The most compelling feature of the Wapama, aside from its 69 years of age, is the use of sister frames and the apparent non-use of steel strapping. As noted above, the use of steel strapping was a classification society requirement for vessels of the Wapama's size. Yet analysis of the effectiveness of the sister frames shows that they provide a substantial amount of stiffness to the hull within the region where they are used. This stiffness is achieved because frame rigidity is greatly increased since the sister

frames fill the voids between the complete frames and develop a solid network of timber material. It is also evident that the number of fastenings are increased by 50% in the area of the sister frames. This arrangement of frames would allow horizontal shear to be carried by a solid network of vertical timbers, and vertical shear to be carried by a solid network of lateral planking.

The Wapama exhibits other variations in construction than appear to have been recommended at the time. Survey indicates that less metal fastenings and more treenails were used than allowed by ABS. The construction of floor timbers utilized a system of "naval timbers," which was definitely discouraged by ABS, and allowed only infrequently on vessels.

The naval timber method of bottom construction provides a relatively weak arrangement of floor timbers, and could be partially responsible for the extreme set-up of the bottom structure. However, regarding the wooden trunnel fastenings, hull planking removals indicated that the metal fastenings had deteriorated significantly so that effective fastening was accomplished by the trunnels.

3.0 INTENT

It is the intent of this Restoration Program and the accompanying plans and charts to describe the procedure which will be used in the restoration and restructuring of the SS Wapama. In accordance with the Specifications

for Restoration of the SS Wapama submitted in 1980, the preparation method and use of progress schedules detailing the restoration work to be done will be presented herein.

Previous surveys and structural analysis of the vessel's hull and timbers have located those areas where restoration and replacement structures are most needed. For the purpose of this restoration program these designated areas are divided according to their major structural importance and then into categories of components and locations. The purpose of providing these designations is to show a clear appraisal of the new structure required, and to allow a definitive progress of the restoration to be plotted. This progress will be shown as a series of goals or plateaus that will be achieved as each major structural weakness is repaired.

Due to the relationship that each structural part has to the whole, restoration which involves substantial removal of material must be planned so that the parts which are left in place do not deform or collapse. For this reason the restoration is presented in a sequenced format which is in large part determined by the need to maintain the vessel's shape. In some instances, temporary structures will be used to achieve the desired alignment and to provide strength during restoration and replacement of parts.

4.0 GENERAL DESCRIPTION OF RESTORATION PROGRAM

The Wapama will be restored over a period of years, using a step-by-step sequence of repair work. This sequence will be shown as a number of

phased project goals. Significant weaknesses in the Wapama's longitudinal timbers and frames will be repaired by replacement structures according to the sequence.

Main longitudinal girders for keel, keelsons, waterways, lockstrakes and deck stringers will be replaced in accordance with original design. Some variations in ceiling, ceiling extension and hull shear planking will be allowed over original, specifically relating to edge fastening. However, unique features of the transverse framing arrangements will be preserved by replacement with duplications of original.

The vessel will be restored to as close an approximateion of her original form as is practicable. With the vessel securely supported at selected locations, the bottom structure and side planking will be removed to allow the vessel to relax and to reestablish her true keel line. Restructuring of bottom girders will be made from the true keel line.

5.0 PREPARATIONS TO REPAIR DEFICIENCIES

During the period of years over which the restoration is expected to extend, the hull timbers and replacement timbers will be exposed to the elements, possibly creating damage from sun, rain and wind. Protection from the elements will be provided by an enclosure which would also allow year-round work. This enclosure would be constructed as part of the initial restoration phase.

The main propulsion engine, auxiliaries and other engine room equipment are to be removed for the express purpose of relieving weight upon the after hull timbers.

The aft fuel oil tanks in the engine room, port and starboard, shall be removed within the area of restructuring. The platform deck in the engine room, aft of the fuel oil tanks shall be removed, along with the pumps, generators and other machinery in the same general area, for access during restructuring. Items removed from the engine room shall be replaced upon completion of the hull restructuring.

The Fwd Tween Deck shall be removed where required to facilitate the replacement of the ceiling. The tween deck transverse angle iron beams shall be chipped, primed with red lead and reinstalled with new brackets, fittings and timber bracket backings where required.

The fidly and boat deck above the engine room casing shall be removed to provide access to the engine room and main deck longitudinal girders.

6.0 EXISTING STRUCTURAL DEFICIENCIES

The Wapama is significantly deficient in three specific hull locations:

FOREBODY FRMS	3 - 12
MIDBODY FRMS	12 - 42
AFTERBODY FRMS	58 - 68

Each location exhibits characteristics which show certain structural replacements are required. The requirements are based upon floating integrity, maintaining form and repair of beams and girders which are mostly rotted or fractured. Replacements are not required during this program where a structural part retains a majority of its original strength—50% or more.

SECTION II - PRINCIPAL RESTORATION GOALS

1.0 MAJOR STRUCTURAL SYSTEMS

Every vessel is designed on the basis of simple beam theory, where the hull is considered to be capable of a continuous distribution of stress from bow to stern and deck to keel. To accomplish this, the vessel is constructed using not one but a number of structural systems which perform separate as well as dependent functions. The progress of the restoration effort for the Wapama will be judged by work accomplished in each major structural system as described in this part and in Drawings 002 to 005.

Each major system is represented by its members, the total boardfeet and the net damaged boardfeet to be removed or repaired. This boardfeet figure for the repair does not include the scarph lengths or joint shifts of the new timber installed.

2.0 LONGITUDINALLY CONTINUOUS GIRDERS

This structural system is shown in Drawing 002. It involves members which establish the preliminary hull form, provide the foundation for other longitudinal girders and transverse frames, and create the longitudinal continuity which the hull must have in order to conform to beam theory.

Longitudinal continuity is maintained when there are no rapid changes in the sizes of the vessel's girders. If the main longitudinal members are locally damaged or become decayed, the effect is to create a rapid change

in effective girder size between damaged and undamaged parts. This alters the stress flow and will create stress concentrations. The same problem of stress concentration would exist in a girder that is uniformly rotted, and a local area only is reinforced. In other words, if a repair to a longitudinal girder is to be effective, it must contribute to the continuity of the member by extending a distance beyond the damaged area, tapering into the older existing structure. Continuity also involves connections that must be tapered using properly spaced and proportioned scarf joints in adjoining and adjacent timbers.

The Wapama's longitudinal girders are:

A keel 16" x 19-1/2", extending from frame 1 to 80 with 5200 BDF. Repair will involve 3965 BDF.

A keelson 18" x 19-1/2", extending from frame 1 to 70 with 5119 BDF. Repair will involve 2300 BDF.

A 1st rider keelson 18" x 19-1/2", extending from frame 2 to 54 with 3800 BDF. Repair will involve 2300 BDF.

A 2nd rider keelson 18" x 19-1/2", extending from frame 2 to 54 with 3800 BDF. Repair will involve 2300 BDF.

A 1st sister keelson 24" x 18-1/2", port and starboard extending from frame 7 to 68 with 11300 BDF. Repair will involve 5600 BDF.

A 2nd sister keelson 21" x 18", port and starboard extending from frame 7 to 68 with 9610 BDF. Repair will involve 4260 BDF.

A 3rd sister keelson 18" x 18", port and starboard extending from frame 14 to 62 with 6480 BDF. Repair will involve 3510 BDF.

A waterway 10" x 14-1/2", port and starboard extending from frame 1 to 80 with 4780 BDF. Repair will involve 3687 BDF.

A lockstrake 12" x 12", port and starboard extending from frame 1 to 80 with 4740 BDF. Repair will involve 3540 BDF.

A longitudinal deck girder 13" x 14", port and starboard extending from frame 9 to 70 with 4630 BDF. Repair will involve 4170 BDF.

A top longitudinal deck girder 16" x 12", port and starboard extending from frame 9 to 70 with 4880 BDF. Repair will involve 3650 BDF.

A companion longitudinal deck girder 11" x 14", port and starboard extending from frame 9 to 70 with 3920 BDF. Repair will involve 3530 BDF.

3.0 TRANSVERSE RING

The transverse ring in a timber vessel performs two functions. First, it creates the ribs of the vessel, giving breadth. Second, it acts as a shear path for stresses developed in longitudinal bending. This shear path is from the deck to the keel. Transverse frames are important in developing the vessel's longitudinal rigidity. Weak, damaged or poorly fastened transverse frames will cause a timber vessel to bend excessively.

The transverse ring involves all the structures which are connected to form the vessel's sections. Because of the roundness of some of these sections, specifically at the bilge the framing members must be made up into sawn crescent-like parts.

Each part of the transverse ring which creates the form of the vessel's frames is called a futtoch. The futtochs on the Wapama are connected by scarfs only at the first futtoch. Above that the connections are butt joints. The connections which carry the most stresses are at the first and second futtoch, and these are the ones which cause the most severe frame deformation. This deformation appears as a characteristic set up or hump in the vessel's bottom timbers. For the Wapama the combination of longitudinal and transverse hogging shows a particularly serious problem.

The transverse ring acts in association with and is supported by the major longitudinal girders. The Wapama's transverse ring is composed of:

Floors 15-1/2" x 10-1/2" at each frame from 6 to 67 with 11600 BDF. Repair will involve 12938 BDF.

Naval timbers 15-1/2" x 10-1/2" at each frame from 6 to 67 with 23500 BDF. Repair will involve 17489 BDF.

Side frames 15-1/2" x 10-1/2" at each frame from 1 to 81 with 21700 BDF. Repair will involve 15380 BDF.

Sister frames 15-1/2" x 9" at each frame from 19 to 38 with 4420 BDF. Repair will involve 1400 BDF.

Long top timbers 15-1/2" x 10-1/2" and tapered at each frame from 1 to 66 with 17640 BDF.

Short top timbers 13-1/2" x 10-1/2" and tapered at each frame from 1 to 66 with 18500 BDF.

Beam knees 5' x 5'6" x 16" at every deck beam for a total of 45 locations with 11340 BDF.

Deck beams 14" x 16" at every beam knee location for a total of 45 locations with 28560 BDF.

Transverse bulkhead of steel construction located at frames 2, 47 and 71.

Hold stanchions 7-1/2" x 14" at deck beams for a total of 18 locations with 1600 BDF.

Hatch carlings 14" x 16" located at each hatch side from frames 25 to 35 and 51 to 67 with 2430 BDF.

Hatch coamings 26" x 12" located at each hatch end at 4 locations with 1360 BDF.

4.0 CEILING

The ceiling of a timber vessel is an important element of both the longitudinal and transverse systems. Generally the ceiling is the interior longitudinally laid planking within the vessel's bilge radius. Located near the vessel's flexural center, it contributes greatly in resistive shear, enabling the top and bottom structures of the vessel to resist bending more effectively. But the ceiling is only marginally effective if the fastenings are inadequate in number or substantially wasted. It is the fastenings which force the vessel's ceiling timbers to work together, and these are both edge fastenings of each ceiling timber to its neighbors, as well as fastenings of the ceiling to the frames. Where the interior of the vessel is ceiled above and below the bilge, this is referred to respectively as side and bottom ceiling extensions. When the ceiling is extended the vessel's longitudinal strength is substantially increased. For vessels of the Wapama's size or greater, the hull must be entirely ceiled in order to provide the necessary longitudinal strength.

The Wapama's ceiling specifications are:

Ceiling 10" x 15", port and starboard extending from frame 1 to 80 as strakes K through O with 29700 BDF. Repair will involve 18500 BDF.

Bottom ceiling extension 10" x 16", port and starboard extending from frame 1 to 76 as strakes D through J with 35000 BDF. Repair will involve 27700 BDF.

Side ceiling extension 10" x 14", port and starboard extending from frame 1 to 80 as strakes R through V with 23042 BDF. Repair will involve 1167 BDF.

5.0 HULL AND DECK PLANKING

Hull and deck planking are the principal watertight barriers for the vessel. Although they contribute strength, for a vessel the size of the Wapama these planking surfaces do not constitute principal structural members. For both hull and deck planking, edge fastening is not specified as a construction requirement. This means that the shear boundary for these members is the plank edge, with contributions from friction only. Caulking these plank edges not only produces a watertight seam, it also improves the frictional adherence of each plank edge to its neighbor. Loose or rotted caulking will diminish the longitudinal rigidity of the hull.

Two hull plank strakes serve a special purpose, namely establishing hull alignment and form. These strakes are the garboard strake and the plank sheer.

The garboard strake is edge fastened and is adjacent to the keel. Generally considered as contributing strength to the keel, the garboards are laid and set before the hull is ceiled and planked.

The plank sheer is the uppermost strake at the main deck level. This planking is laid against the short top timbers of the frames and is used to establish the vessel's sheer line as well as frame alignment during the early stages of construction.

Deck planking generally contributes as much strength to the vessel as the longitudinal deck girders contribute. Specifications for deck planking always require the planks to be edge laid. This insures that the greatest strength from the plank is aligned with vertical loads which would be developed by deck cargoes.

Although deck planking may be caulked and pitched some time prior to the vessel's launching, the hull planking is caulked shortly before launching to insure watertightness.

Planking requirements for the Wapama are:

A garboard 6" x 18", port and starboard extending from frame 1 to 80 as strake A with 3555 BDF. Repair will involve 2835 BDF.

A garboard 5" x 18", port and starboard extending from frame 1 to 80 as strake B with 2970 BDF. Repair will involve 2362 BDF.

Bottom planking 4-1/2" x 18", port and starboard extending from frame 1 to 80 as strakes C through M with 26700 BDF. Repair will involve 17000 BDF.

Bilge planking 4-1/2" x 14", port and starboard extending from frame 1 to 80 as strakes N through V with 18700 BDF. Repair will involve 5337 BDF.

Side Planking 4-1/2" x 9", port and starboard extending from frame 1 to 80 as strakes W through Z with 5340 BDF. Repair will involve 2273 BDF.

Sheer planking (top water) 4-1/2" x 9", port and starboard extending from frame 1 to 80 as strakes Z1 to Z4 with 5340 BDF. Repair will involve 4080 BDF.

Plank sheer 4-1/2" x 12", port and starboard extending from frame 1 to 80 as the sheer line above strake Z4 with 3600 BDF. Repair will involve 1362 BDF.

Main Deck Planking 4" x 4", port and starboard extending from frame 1 to 80 with 20000 BDF. Repair will involve 11545 BDF.

6.0 REPAIR OF STRUCTURAL SYSTEMS

Each major structural system has been described in terms of its components. The relationships that these systems have to each other may also be described as component relationships. Generally component groups from each system support and/or complete a specific structural matrix. In the construction of a vessel, these structural groups are erected in a sequence where they are usually self-supporting and continually build the strength and form the hull. In other words, they are not required to carry any other structures until they are adequately prepared or reach the required stage of strength to do so. Within this restoration program, the repair will involve substantial removal and refitting within structural groups. Because the hull form is distorted and the strength is lost in these repair areas, the greatest difficulty in removing large structural segments will be to maintain the vessel's form and alignment.

This difficulty is greatly reduced when the restoration program follows a procedure which utilizes the strength of repaired segments in a method as close to new construction as possible. This concept is developed by grouping the components of the major structural systems into procedural goals and repair plateaus. Each plateau marks the repair of a major structural weakness or the repair of a foundation. These groups enable inter-

relationships and repair achievements to be made clear. These repair plateaus are also used to explain the sequence of the restoration program which is detailed in Section III.

Each repair plateau is explained in terms of its components, and its significance as a plateau or repair goal. The repair boardfeet which is tabulated with each plateau represents the total boardfeet of the new members installed, including scarph joint lengths and spacing or "shift" of joints in adjacent members.

6.1 Longitudinal continuity is divided into three repair plateaus:

Plateau L-1

Members: keel, keelson, 1st rider keelson, 2nd rider keelson, 1st sister keelson, 2nd sister keelson, 3rd sister keelson.

Total boardfeet is 45310. Repair boardfeet is 30857.

Restoration scope involves removing the vessel's 30" hog and repair of those components which maintain longitudinal form; providing the foundation for floor attachments; providing foundations for deck beam support stanchions; providing keel block landings.

Plateau L-2

Members: waterway, lockstrake.

Total boardfeet is 9520. Repair boardfeet is 8070.

Restoration scope involves repairing those components which provide longitudinal deck strength.

Plateau L-3

Members: longitudinal deck girder, top deck girder, companion deck girder.

Total boardfeet is 13430. Repair boardfeet is 11850.

Restoration scope involves repairing those components which provide longitudinal deck strength.

6.2 Transverse ring structure is divided into six repair plateaus.

Plateau T-1A

Members: forebody and afterbody floors and naval timbers. Frames 1 to 20 and 48 to 80.

Total boardfeet is 39528. Repair boardfeet is 13290.

Restoration scope involves providing a reinforced area at the bow and stern so that longitudinal alignment of the midbody may be accomplished.

Plateau T-1B

Members: midbody floors and naval timbers. Frames 20 to 48.

Total boardfeet is 21228. Repair boardfeet is 17137.

Restoration scope involves establishing the base line for the transverse hull sections.

Plateau T-2

Members: side frames, sister frames.

Total boardfeet is 61272. Repair boardfeet is 16680.

Restoration scope involves establishing the bilge radius and shape of the transverse sections; providing transverse strength and planking surfaces.

Plateau T-3

Members: short top timbers, long top timbers.

Total boardfeet is 36140. No new material is required.

Restoration scope involves completing the shape of the transverse frames; providing the surface for the plankshеer; establishing and maintaining alignment.

Plateau T-4

Members: beam knees, deck beams, hold stanchions.

Total boardfeet is 41500. No new material is required.

Restoration scope involves completing the shape of the transverse sections; providing the surface for the waterway, lockstrake and deck girders.

Plateau T-5

Members: hatch carlings, hatch coamings.

Total boardfeet is 3790. No new material is required.

Restoration scope involves providing reinforcing structure for hatch opening so that both transverse and longitudinal alignment is maintained within the hatch cut-out.

Plateau T-6

Member: transverse bulkheads. These members are essentially steel in construction. Timber sheathing is present on the forward face of the engine room bulkhead at frame 47.

Restoration scope involves providing transverse shape at these bulkhead locations.

6.3 Ceiling timbers are divided into three repair plateaus.

Plateau C-1

Member: bottom ceiling extension strakes D through J.

Total boardfeet is 35000. Repair boardfeet is 29682.

Restoration scope involves preserving the longitudinal alignment of keelsons and floors.

Plateau C-2

Member: ceiling strakes K through O.

Total boardfeet is 29700. Repair boardfeet is 24164.

Restoration scope involves preserving the transverse shape and alignment of the transverse frames within the restored area; contributing longitudinal strength.

Plateau C-3

Members: Side ceiling extension strakes R through V.

Total boardfeet is 23042. Repair boardfeet is 1809.

Restoration scope involves providing a surface for the beam knees.

6.4 Hull and deck planking is divided into four repair plateaus.

Plateau P-1

Member: garboard strakes A and B.

Total boardfeet is 6525. Repair boardfeet is 5544.

Restoration scope involves providing longitudinal reinforcement to the keel; providing alignment of floors and naval timbers.

Plateau P-2

Members: plank sheer.

Total boardfeet is 3600. Repair boardfeet is 1360.

Restoration scope involves providing alignment for side frames; establishing the vessel's sheer profile.

Plateau P-3

Members: bottom planking, bilge planking, side and top water planking.

Total boardfeet is 56080. Repair boardfeet is 28690.

Restoration scope involves finishing the vessel's form and longitudinal strength; providing the watertight surface.

Plateau P-4

Members: main deck planking.

Total boardfeet is 20000. Repair boardfeet is 11545.

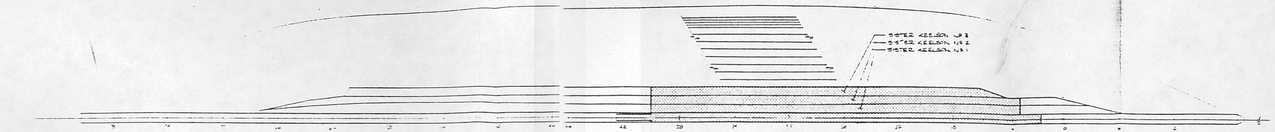
Restoration scope involves providing the main deck with additional longitudinal strength; providing the main deck form.

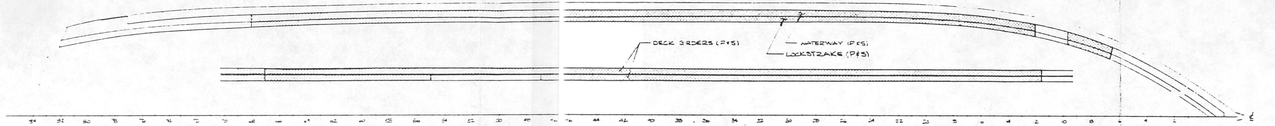
LONGITUDINAL CONTINUOUS MEMBERS

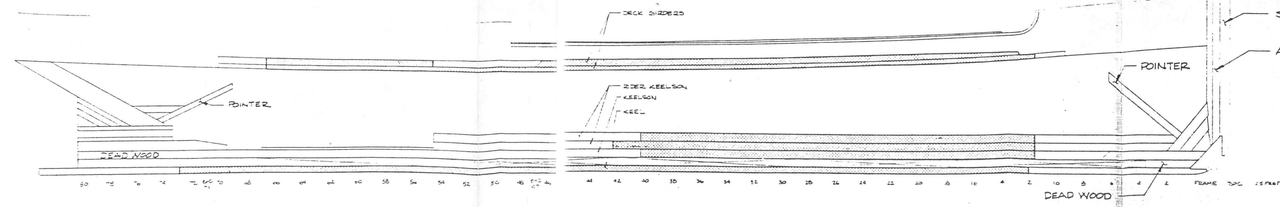
COMPONENT MEMBERS				REPLACEMENT AREAS (NET)			
ITEM	LOCATION	SCANTLING	BOARD FEET	LOCATION	BOARD FEET	LENGTH AND OR # PARTS	RESTORATION PLATEAU
KEELSON	FRAMES 1-70	8" x 19 1/2"	5118.5	FRAMES 11-91	2300.0	~79 FT	L-1
1ST RIDER KEELSON	FRAMES 2-54	18" X 19 1/2"	3800	FRAMES 11-93	2300	"	L-1
2ND RIDER KEELSON	FRAMES 2-59	18" X 19 1/2"	3800	FRAMES 11-91	2300	"	L-1
1ST SISTER KEELSON	FRAMES 7-68	24" x 18 1/2"	11300	FRAMES 13-40	5600	~135 FT	L-1
2ND SISTER KEELSON	FRAMES 7-66	21" x 18"	9610	FRAMES 13-90	4240	"	L-1
3RD SISTER KEELSON	FRAMES 14-62	18" x 18"	6480	FRAMES 9-90	3510	130'0 FT	L-1
WATERWAY	FRAMES 1-80	10" x 14 1/2"	4780	FRAMES 7-68	3687	300-0 FT	L-2
LOOKSTRAKE	FRAMES 1-80	12" x 12"	4740	FRAMES 7-68	3590	300'0FT	L-2
LONGITUDINAL DECK GIRDER	FRAMES 9-69	13" x 14"	4630	FRAMES 12-69	4170	300'0FT	L-3
TOP LONGITUDINAL DECK GIRDER	FRAMES 19-69	16" x 12"	4880	FRAMES 13-69	3650	2300FT	L-3
COMPANION LONG. DECK GIRDER	FRAMES 9-69	11" x 14"	3920	FRAMES 12-69	3530	300'0FT	L-3
KEEL	FRAMES 1-80	16 x 19 1/2	5603	FRAMES 12-73	3965	152-5	L-1

KEY

RENEWALS







US DEPARTMENT OF INTERIOR
NATIONAL PARK SERVICE

VESSEL: S.S. WAPAMA

TITLE: LONGITUDINAL GIRDER REPLACEMENT

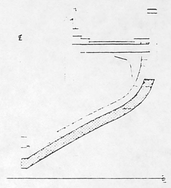
ZACHARY M. REYNOLDS
NAVAL ARCHITECT

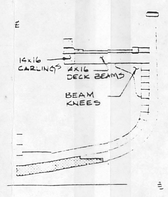
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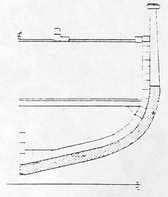
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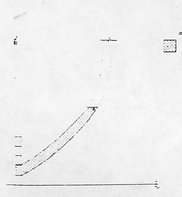
TRANSVERSE RING

COMPONENT MEMBERS				REPLACEMENT AREAS			
ITEM	LOCATION	SCANTLING	BOARD FEET	LOCATION	BOARD FEET	LENGTH AND OR # PARTS	RESTORATION PLATEAU
NAVAL TIMBERS	FRAMES 5 - 67	15½" x 10½"	23500	FRAMES 5-9, 12-19, 59-67	17289.0		T-1
FLOORS	FRAMES 5-67	15½"x10½"	11600	FRAMES 5-9, 12-19, 59-67	12938.0		T-1
SISTER FRAMES	FRAMES 19-38	15½" x 9"	4420	FRAMES 19-24	1400		T-2
SIDE FRAMES	FRAMES 1-81	15½" x 10½"	21700	FRAMES 14-A, 68-80	15380.0		T-2
SHORT TOP TIMBERS	FRAMES 1-66	13½" x 10½"	13500				T-3
LONG TOP TIMBERS	FRAMES 1-66	15½" x 10½"	17690				T-3
DECK BEAMS	@ BEAM KNEE LOCALES (₸,9S)	14"x16"	28560				T-4
TRANSVERSE BULKHEADS	FRMS - 2, 47 AND 71		STEEL				
HOLD STANCHIONS	AT DECK BEAMS (₸,18)	7½" x 14"	1600				T-4
HATCH CARLINGS	FRMS 25-35 51-67	14" x 16"	2430				T-5
HATCH COAMINGS	AT EACH HATCH (₸,9)	26" x 12"	1360				T-5
BEAM KNEES	FRAMES @ 45 LOCATIONS	5' x 5'-6" x 16"	11340				T-4



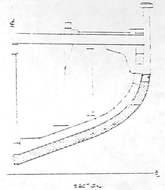


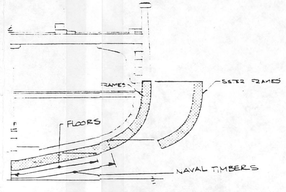


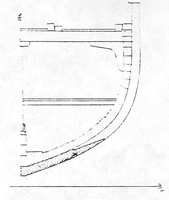


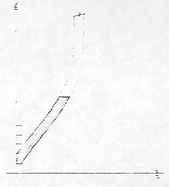
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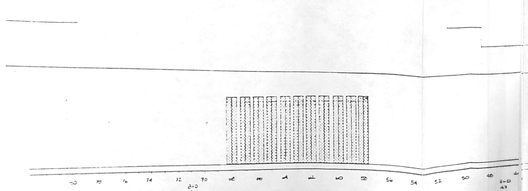


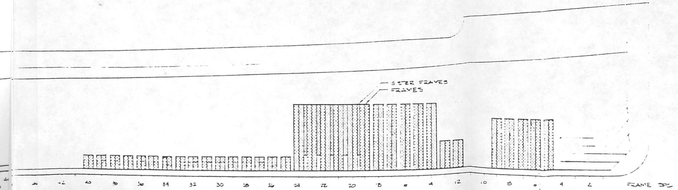






NOTES: SCALE FOR ALL SECTIONS AS 1"=1'-0"





US DEPARTMENT OF INTERIOR
NATIONAL PARK SERVICE

VESSEL: S.S. WAPAMA

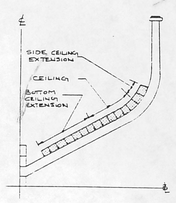
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ZACHARY M. REYNOLDS
NAVAL ARCHITECT

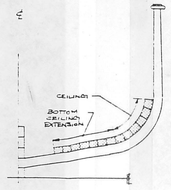
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CEILING

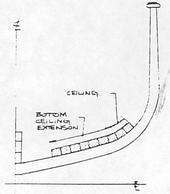
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ITEM	LOCATION	SCANTLING	BOARD FEET	LOCATION	BOARD FEET	LENGTH AND # PARTS	RESTORATION PLATEAU
CEILING	FRAMES 1-80	10" X 15" 10" X 14"	29700	FRAME 5-54, 58-68	18500		C-2
BOTTOM CEILING EXTENSION	FRAMES 1-76	10"X16"	35000	FRAME 5-54, 58-68	22700		C-1
SIDE CEILING EXTENSION	FRAME 1-80	10" X 14"	23092	FRAME 5-54, 58-68	1167.0		C-3



FRM 67



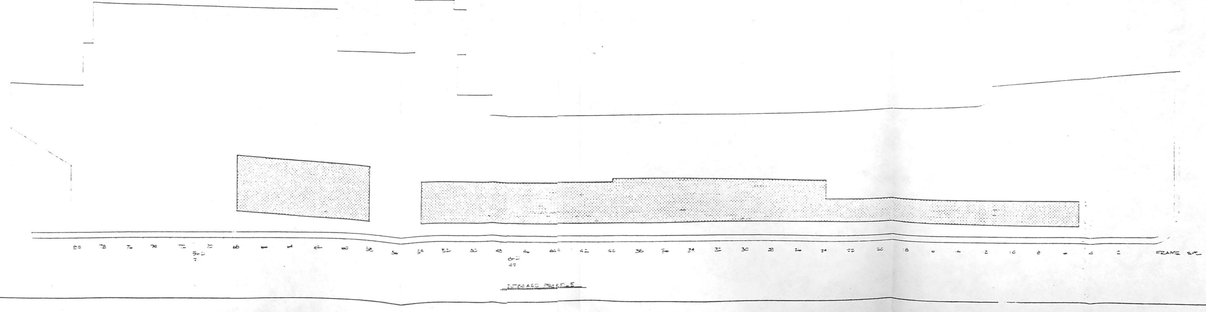
FRM 31



FRM 19

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RENEWAL



LENGTH PARTS

U.S. DEPARTMENT OF INTERIOR
NATIONL PARK SERVICE

VESSEL: S.S. WAPAMA

TITLE: CEILING REPLACEMENT

ZACHARY M. REYNOLDS
NAVAL ARCHITECT

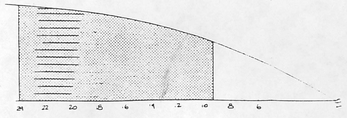
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SCALE: 1/2"=1'-0" | DRAWING NO.: 004

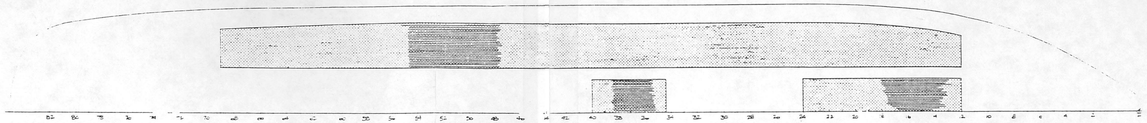
PLANKING

COMPONENT MEMBERS				REPLACEMENT AREAS			
ITEM	LOCATION	SCANTLING	BOARD FEET	LOCATION	BOARD FEET	LENGTH AND OR # PARTS	RESTORATION PLATE #
GARBOARD A	FRAMES 1-80	6" x 18"	3555	FRAME 5-68	2835.0		P-1
GARBOARD B	FRAMES 1-80	5" x 18"	2970	FRAME 5-68	2362.0		P-1
BOTTOM PLANKING	FRAMES 1-80	4½" x 18"	26700	FRAME 5-68	17000		P-2
BILGE PLANKING	FRAMES 1-80	4½" x 14"	18700	FRAME 5-68	5337.0		P-3
SIDE PLANKING	FRAMES 1-80	4½" x 9"	5290	FRAME FP - 34	2273.0		P-3
SHEER PLANKING	FRAMES 1-80	4½" x 9"	5340	FRAME FP - 68	4080.0		P-3
PLANK SHEER	FRAMES 1-80	4½" x 12"	3600	FRAME 12-68	1360.0		P-2
MAIN DECK PLANKING	FRAMES 1-80	4" x 9"	20000	FRAME 12-69	11545.0		P-9
TWEEL DECK PLANKING	FRAMES 9-29	2½" x 16"	2500	FRAME 9-29	2500		
TWEEN DECK TIMBER FILLERS	FRAMES 9-29	4" x 6"	900	FRAME 9-29	900		
TWEEN DECK ANGLE	FRAMES 9-29	∠ 6½" x 4" x 3/8"	STEEL 450 FT LENGTH	FRAME 9-29	STEEL 450 FT LENGTH		
FORECASTLE SIDE PLANKING	FRAMES FP- 12	4" x 6"	2736	FRAME FP - 8	2016		
FORECASTLE DECK PLANKING	FRAMES FP - 12	4" x 4"	2904	FRAME FP - 12	2904		

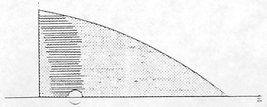
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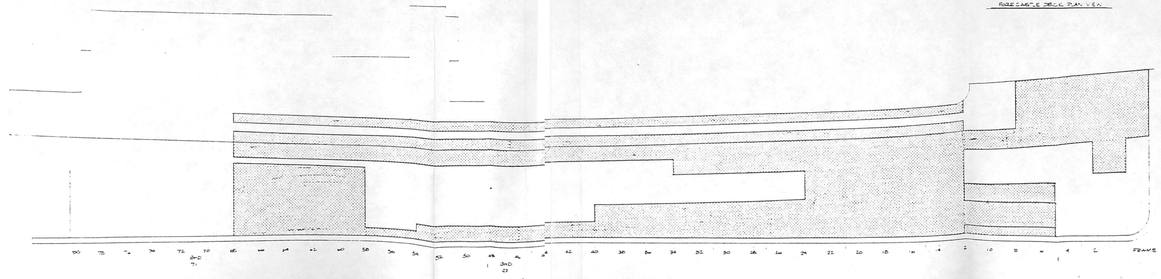
TWEEN DECK PLAN VIEW



MAIN DECK PLAN VIEW



FORECASTLE DECK PLAN VIEW



STAGGERED JOINTS

US DEPARTMENT OF INTERIOR NATIONAL PARK SERVICE	
VESSEL	SS. WAPAMA
TITLE	SIDE SHELL & DECK PLKG REPLACEMENT
	ZACHARY M. REYNOLDS NAVAL ARCHITECT
DATE 14 MAY 84	DRAWN BY [illegible] CHECKED BY [illegible]
SCALE 3/4"=1'-0"	DRAWING NO. 005

SECTION III - SEQUENCE OF RESTORATION

1.0 INTERRELATED SYSTEMS

Wooden vessels rely upon bolt type fastenings to carry shear across seam and butt joint boundaries. These fastenings force adjacent parts to work together, thereby developing lateral and vertical resistive shear components. Unfortunately these attachments are not as efficient as joints which are made with a continuous deposit of fastening material, such as a weld. For example, in a steel vessel of welded construction, the horizontal component of shear is carried in the steel plate which forms a continuous shell around the vessel. In a vessel of timber construction, using planks and frames, the horizontal shear from the planks is resisted by the vertical frames, and is transmitted to the frames by the fastening bolts or spikes. The frames of a timber vessel provide two services. They form the transverse shape of the hull and provide a path for the internal resistive shear which keeps the vessel's parts working together.

Because of the wooden vessel's limitations on joint connections, the interrelationship of connected parts is of major significance. Attempts have been made at a compromise in this problem of shear transfer, and some have proved to be quite successful. Most notable of these successes is the use of diagonal carvel planking. However, the Wapama does not use this system, and relies heavily upon the horizontal/vertical fastening matrix. Within this system certain dependencies establishing hull girder strength must be maintained. These are briefly outlined as follows:

1. Vertical frames are dependent upon lateral planking and ceiling to transmit internal resistive shear in bending.

2. Longitudinal continuous girders provide end conditions to transverse frames so that the horizontal resistive shear has an equal and opposite end reaction.

3. Deck beams and deck longitudinal girders provide an intercostal type of grillage which maintains deck strength and shape.

Also within this system, specific structures determine the vessel's form:

1. Keelsons, which establish the backbone of the hull.

2. Sheer strakes, which establish the profile of the hull.

3. Waterway, which maintains the transverse and longitudinal alignment of the frames.

4. Deck girders, which maintain deck strength and shape as previously presented.

Any sequence of construction or repair must account for these considerations of strength and form when dealing with a wood vessel. Failure to do so will result in varying degrees of built-in twist or longitudinal deformation.

2.0 STRESS RELIEF

The Wapama's biggest problem is that its structure has deteriorated to the point where it is not adequate to carry the weight of the existing hull and machinery. In order to reduce this problem it is necessary to remove those items which create the most severe concentration of weight. It is also advantageous to remove any items of weight which do not require an exceptional effort to remove. The items which are the best candidates for early removal are:

1. Main deck fidley house.

2. Main steam triplex engine.

3. Main boilers.

4. Fuel oil tanks.

5. Forward tween deck.

6. All deck machinery.

3.0 RESTORATION SEQUENCE

As the planning of the restoration reaches the final stage, two facts must be clearly understood.

1. The Wapama's hull is distorted and weak throughout its length.

2. The interrelationship of the Wapama's structural parts may not be fully developed between the restored areas and those areas left "as is."

When the actual work is under way, some areas which are not anticipated to be restored may required substantial repair before adequate attachments to new material can be made. Although the sequence presented may be followed in nearly all conditions, some conditions not anticipated may require a reassessment of the planned repair.

3.1 Sequence 1 will involve repair of the bow between frames 6 to 12. The plateaus will include T-1A, C-1, P-3 and P-2. The scope of this sequence will be to repair the bow so that a strong point is provided for a secondary hull support and anchor. This anchor will also support the bow section which is cantilevered over the end of the graving barge. The forepeak floors and panting frames will be repaired. The tween deck will be removed along with the ceiling and planking.

The extent of this repair covers the floors, bottom planking, bottom ceiling extension, focsle side planking and top water.

The procedure will be to remove the bottom, side and focsle planking to gain access to the frames. The bottom ceiling extension which is scheduled for renewal will also be removed. The floors and naval timbers at frames

5 to 9 are to be split and removed. All fastenings through the keel and keelsons are to be pulled. The new floors and timbers are to be installed.

3.2 Sequence 2 will involve removals of deck structures over the engine room trunk. The scope of this sequence is to provide overhead crane access to the engine room. This will also expose main deck longitudinal girders which require replacement.

The extent of the removal includes the engine room fidley and deck house structure, as well as the navigation bridge. The procedure will be to disconnect all deck house fastenings at the main deck level. Detach the deck house from the superstructure at frame 60. Internal bracings and supports are to be provided to the deck house. Remove the deck house with a crane and place it in a shore side work area.

3.3 Sequence 3 will involve repair to the stern between frames 58 to 68, and the removal of engine room equipment. The plateaus will include L-1, T-1A, T-2, C-1, C-2, C-3, P-1, P-2, P-3. The scope of this sequence will be to remove the main propulsion engine and various equipment in order to reduce the strain on the main hull girder. Planking and frame removals will also provide access to the stern. An anchor point at this stern area will also be provided for secondary support structures. The stern frames and floors will be repaired.

The extent of this sequence covers the stern frames, ceiling, planking, and equipment removal.

The procedure will be to remove the bottom and side planking first. The engine room wing tanks are to be split and moved inboard to facilitate work on the ceiling. The bottom ceiling extension and bilge ceiling are to be removed. Engine room equipment is to be removed through the main deck cut out, or may be moved out through the side after floors and frames are removed.

3.4 Sequence 4 will involve the construction of an external structure. The purpose of this structure will be to provide an all weather cover for the vessel, specifically those areas where the outer hull is to be repaired.

The cover will be designed to allow overhead crane work, and provide side access through large doors or removable partitions.

3.5 Sequence 5 will involve repair of the main deck between frames 12 to 69. The restoration plateaus will include L-2, L-3 and P-4. The scope of this sequence will be to remove all main deck longitudinal structures and deck planking. This will be in preparation for relaxation of the hull girder as well as main deck repair. The bow and stern secondary structures will be installed to maintain alignment and provide support to the hull.

The extent of the repair covers the main deck planking and deck girders.

The procedure will be to remove all deck planking between frames 12 to 69. The longitudinal deck girders and the waterways port and starboard will be removed, with fastenings being pulled from deck beams and top

frame timbers. Temporary girders are to be provided at the vessel's sides and secured to the top frame timbers. These girders are to maintain longitudinal frame alignment. Structural anchors are to be installed at the bow and stern locations to provide secondary support tie-in. These anchors will also maintain transverse alignment between the bow and stern, preventing twisting of the hull during the extended repair period.

3.6 Sequence 6 will involve repair of the midbody between frames 12 to 54. The plateaus will include C-1, C-2, C-1, P-2 and P-3. The scope of this sequence will be to remove all midbody planking and ceiling in preparation for relaxing the hull girder. Access to floors and frames will be provided. Structures intended to maintain control of the hull alignment will be set in place. The supports for the midbody will be removed, allowing the hull to relax, so that the hogging condition is eliminated. The true keel line is to be reestablished.

The extent of the repair covers the removal of planking and ceiling.

The procedure will be to remove the hull planking slated for repair between frames 12 to 60. This includes the garboard strakes. Ceiling timbers between frames 12 to 60 are to be removed. Secondary structures will be constructed so that they carry the vessel's end point loads and relieve the hogging strain in the midbody. These structures will take the general shape of hogging posts landed upon the barge deck. They will connect to the Wapama's bow and stern using cables attached to anchor points on the vessel. A second type of anchor at the vessel's end points will be used to

maintain transverse alignment and permit vertical movement. The keel blocks between frames 12 to 60 will be removed and the hull and keel line lowered with the aid of hydraulic jacks to maintain control of the midbody rate of settling. Using this system, the true keel line will be established Because the transverse frames are also hogged, the true keel line cannot be considered established when the existing keel timber is landed horizontal. This error will produce a technical sag in the main deck line.

3.7 Sequence 7 will involve repair to the midbody and the stern between frames 12 to 80. The plateaus will include L-1, T-1, T-2 and P-1. Plateau achievements, or completions will be L-1 and P-1. The scope of this sequence will be to lay the new keel, repair the keelsons and to repair all midbody floors, naval timbers and frames. The stern frames and floors will also be completed and attached to the keel. The main deck sheer line will be established.

The extent of repair covers the installation of keel, keelsons, frames and floors.

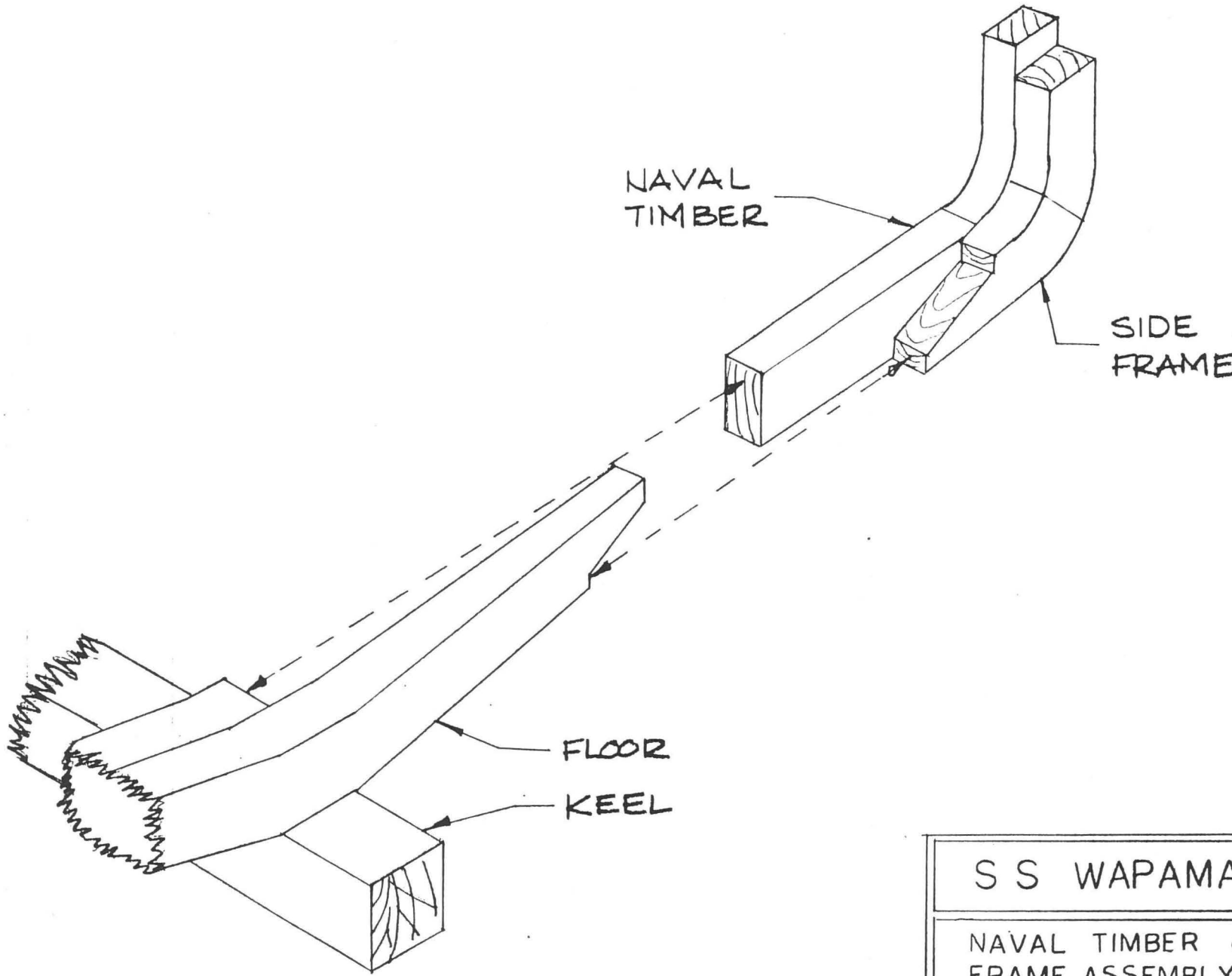
The procedure will be to remove all sections of the keel which are to be repaired. This will involve frames 12 to 78. Keel blocks will require removal to allow access to the timbers. Where keel blocks are removed, side blocking must be increased. Following the removal of the keel, the midbody floors and keelsons will be removed. The true keel line will then be sighted from stem to stern and new keel blocking set at this line. With the new keel timber laid, floor templates will be taken. New floors cut

from these templates will correct the transverse hog or set up that is so noticeable in the midbody of the vessel. With the midbody floors in place, the repair segments of the keelsons will be installed. Sister keelsons and garboards are set in place and fastened. This sequence will mark the completion of the repair plateau L-1 (keel and keelson assembly) and P-1 (garboards).

3.8 Sequence 8 will involve repair to the midbody and bow between frames 5 to 46. The plateaus will include T-1 and T-2. The plateau achievements will be both T-1 and T-2. The scope of this sequence will be to complete the repairs to the frames and sister frames in the midbody. All bow frames requiring repair are also to be completed at this time.

The extent of the repair covers the installation of frames, sister frames and naval timbers.

The procedure will be to template the futtochs between floors and top timbers or frames. All bilge frame areas to repair will be open. Initial side access to these frame areas will be good. As the frames are filled in, access will diminish until the last new frame where the side access will be only 9 inches. This will preclude the normal side fastening method for the new futtoch butts. Where access is limited in this manner, futtoch joints of frame to top timber will be scarfed and fastened through the moulding of the timber similar to the frame to floor scarf. naval timbers will be pre-assembled to the frame futtochs and placed alongside the floors



S S WAPAMA		
NAVAL TIMBER & FRAME ASSEMBLY SKETCH		
SCALE	DATE	REV

after the floors have been secured to the keelsons. After complete assembly of the floors, naval timbers and frame segments, the naval timbers will be fastened to the keelsons.

3.9 Sequence 9 will involve repair to the stern between frame 58 to 68. The plateaus will include C-1, C-2, C-3 and P-2. The plateau achievements will be C-3 and P-2. The scope of this sequence will be to complete the ceiling repairs in the stern and to install a new planksheer for the entire replacement length.

The extent of the repair covers the bottom ceiling extension, ceiling and side ceiling extension in the aft frames of the engine room, and planksheer.

The procedure will be to lay the bottom ceiling extension, and edge fasten each strake. Scarf joints will require 2 frame spaces. The closest continuation of the ceiling repair is 4 frame spaces forward at frame 54. This will allow 4 complete frame spaces to joggle the scarfs for both ceiling repair areas at frames 54 and 58. The final end connections will be made when the repaired ceilings at frame 54 are matched with the required scarf details for frame 58 repairs. The bilge ceiling between frames 58 to 68 will follow the same fastening and scarf arrangements as those laid out for the bottom ceiling extension. The side ceiling extension between frames 58 to 68 does not have a dependency with another repair area within 4 frame spaces, and

may be laid and completed in this sequence 9. The planksheer will be installed so that it maintains the transverse and vertical alignment of the new frame repairs.

3.10 Sequence 10 will involve repair to the forebody and midbody between frames 5 to 54. The plateaus included will also be those completed, and are C-1; C-2. The scope of this sequence will be to complete the ceiling repairs and end connections throughout the vessel, including the scarf joints between frames 54 to 58.

The extent of the repair covers the bottom ceiling, ceiling and side ceiling of the bow and midbody.

The procedure will be to establish ceiling strake lengths which will be most condusive to proper end connections and joint staggering. Ceilings will be laid from the keelsons to the side clamp strakes. All ceilings will be edge fastened, and strakes should be as long as possible. As the ceiling is closed, edge fastening will be made at an angle through the corner of the exposed ceiling edge, and down through the lower 2 strakes. Angled edge fastenings in the way of scarfs will require special details. This sequence will effectively "lock in" the form of the restored vessel. Any residual twist or hog must be reduced or eliminated prior to re-ceiling.

3.11 Sequence 11 will involve repair and replanking of the main deck between frames 10 to 69. The plateaus included and completed will be L-2, L-3

and P-4. The scope of this sequence will be to complete the longitudinal continuity of the vessel and to repair hatch coamings and ceilings. New deck planking will be laid.

The extent of the repair covers the waterways, lockstrakes, longitudinal deck girders, hatch coamings and carlings, and deck planking.

The procedure will be to install the waterways and lockstrakes first and during the sequence 10 repairs to the ceiling. These girders at the sides of the vessel will establish transverse frame alignment and assist in defining the vessel's sheer profile. Longitudinal deck girders will be installed after the waterways have established transverse alignment so that the deck girders run true. Deck planking will be laid after the vessel is ceiled and after the longitudinal deck girders are in place. All temporary structures designed to hold the main deck in alignment may be removed. Tie rods are to be tightened and replaced where necessary.

3.12 Sequence 12 will involve repair to the vessel between frames 1 to 70. The plateau involved and completed is P-3. The scope of this sequence is to complete the replanking of the entire hull.

The extent of the repair covers the bottom, bilge and side hull planking from strakes C through Z4.

The procedure will be to lay the bottom planking first, strakes C through K, since they will involve the straightest length. Next lay the side planking,

strakes W through Z4 due to their straight lengths. This procedure of laying the straightest planks first will allow better edge fitting. Those strakes L through V where the most curvature and form is required will be laid last, and fitted as required. Focsle side planking will also be installed at this sequence, and focsle deck planking will be laid.

3.13 Sequence 13 will involve maintenance of various parts and preparations throughout the hull. The scope of this sequence will be painting, caulking, wedging the ceiling and refloating the vessel.

The extent of repair covers the ceiling wedges, caulking and painting.

The procedure will be to caulk all hull plankings seams and to paint the hull. Shortly before refloating, the ceiling is to be completely wedged. The all-weather protective structure is to be removed from the barge. The hull is to be tested for watertightness, and the vessel refloated. When the vessel is secured at tis outfitting berth, the tween deck will be installed and any further repair work to the focsle area may be accomplished. Main deck machinery, masts and rigging will be installed. The main engine will be replaced in the engine room. The fidly deck house and havigation bridge will be replaced and reconnected to the main deck girders. Continued painting and caulking of deck planks will take place.

4.0 PROGRAMMED REPAIR GOALS

Each major structural system has been identified and placed within a specific repair sequence. The position of these systems and items within the scope of the restoration program would be similar with any other vessel undergoing restoration of this magnitude. It is seldom possible to repair a vessel's timbers in the same sequence as when she was built. For the most part these repairs have an inherent weakness because the same fastening management and sequence cannot truly be duplicated during repair efforts.

For example, the Wapama has been extensively surveyed, and shows some unusual characteristics. As noted previously, the use of naval timbers alongside floors was documented. Specifically seen in those areas which were opened up to survey a weakness, it is now believed that the structural detail and arrangement so documented is in fact a repair to that area exactly of the type considered for this present program.

It might also be concluded that the sister frames were repairs to damaged frame futtochs. Whatever the case may be the detailed structural analysis has determined that certain features of the Wapama have enabled her to develop a certain required hull strength. If these features, and others less strong, are indeed the results of past repairs, then the opportunity to study these techniques should lead to programmed repair procedures for the other historic wood vessels.

The repair goals and sequences developed for the Wapama restoration program are shown in outline on the accompanying chart. The two principal considerations of this grouping is to

1. Maintain alignment.

2. Provide adequate fastening surfaces.

SECTION IV - MATERIAL REQUIREMENTS

1.0 STRUCTURAL TIMBER

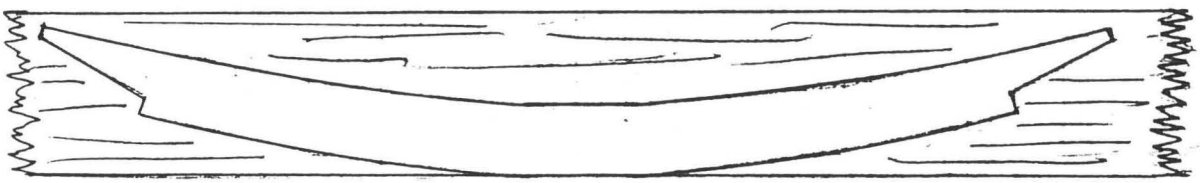
The restoration specifications of 1980 and the latest condition survey of 1982 will provide the basis for material requirements. Each of these documents shows the extent of repair work for all parts of the main hull. With timber construction, the adequacy of the attachment of new parts to old is quite important as explained previously. For this reason, each repaired feature must include the specifications for the attachment as a gross estimate of new timber required. The attachment specifications detail specific points of all attachments:

1. Type of attachment: scarph or butt.

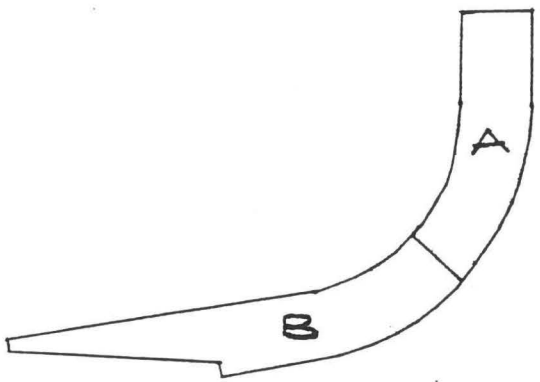
2. Length of scarph cut.

3. Shift of scarphs and butts between adjacent timbers.

The boardfeet of any member which is to serve as a repair for a specific frame location must be increased by twice the scarf length and once by the shift. This is shown in the accompanying sketch. Also included in the estimate of board feet is the amount of waste material or "drop" which occurs as a result of cutting and trimming pieces to fit.

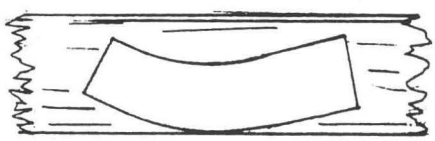


FLOOR (SAWN)
REQUIRES 40% ADDITIONAL MATERIAL

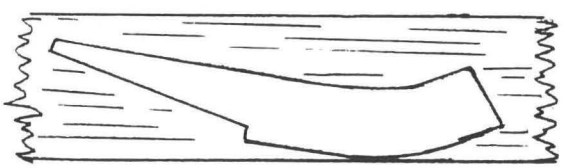


SIDE FRAME (SAWN)
REQUIRES 75%
ADDITIONAL MATERIAL

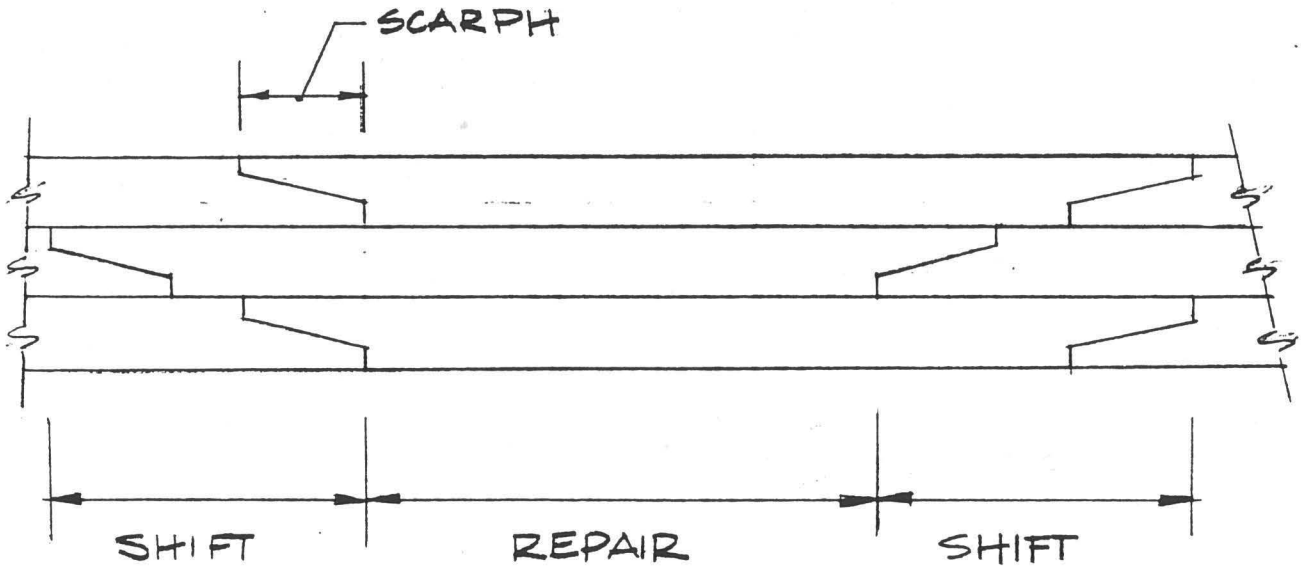
PART A



PART B



S S WAPAMA		
SAWN FRAMES		
SCALE NTS	DATE 1 JUNE 84	REV



REPLACEMENT PLANK
IS INCREASED BY (2) SCARPH
LENGTHS AND (1) SHIFT LENGTH.

S S WAPAMA		
SCARPH & SHIFT ARRANGEMENT		
SCALE NTS	DATE 1 JUNE 89	REV

All boardfeet requirements for the major repair timbers have been presented in Section II. These requirements will now be divided into the specific repair sequences showing net replacement boardfeet and the scarph/shift additions. The percentage of waste material or drop will be assumed to be 10% in most cases. This extra 10% will be added to the replacement boardfeet requirements and will be specified only as "drop," with no separate figure shown. If the percentage of waste material is greater than 10% for a specific member, then that percentage figure will be shown as the drop correction. Removal boardfeet will be expressed as a net value only.

SEQUENCE 1

Removals: 11280 BDF net.

Replacements: 3965 BDF excluding drop.

Floors 5 to 9 - 5 pcs P & S

1804 BDF including scarphs and 40% drop 2526

Naval timbers 5 to 9 - 10 pcs P & S

2162 including scarphs + drop 2378

SEQUENCE 2

Removals: engine room fidley and deck structure.

SEQUENCE 3

Removals: 33709 BDF net.

SEQUENCE 4

Construction: all weather cover for vessel.

SEQUENCE 5

Removals: 33077 BDF net.

Construction: temporary support structures.

SEQUENCE 6

Removals: 55834 BDF net.

Construction: temporary support structures.

SEQUENCE 7

Removals: 53699 BDF net.

Replacements: 57149 BDF excluding drop.

Keel - 12 to 73 - 153 ft.

3965 net + (3 scarph) 468 + drop 4876

Keelson - 12 to 41 - 79 ft.

2300 net + (2 scarphs) 526 + drop 3109

1st Rider Keelson - 12 to 43 - 79 ft.

2300 net + (2 scarphs) 526 + (1 shift) 263 + drop 3398

2nd Rider Keelson - 12 to 41 - 79 ft.

2300 net + (2 scarphs) 526 + (1 shift) 263 + drop 3398

1st Sister Keelson - 13 to 40 - 67.5 ft. P & S

5600 net + (2 scarphs) 1308 + (1 shift) 292 + drop 7920

2nd Sister Keelson - 13 to 40 - 67.5 ft. P & S

4260 net + (2 scarphs) 1134 + (1 shift) 243 + drop 6200

3rd Sister Keelson - 13 to 40 - 65 ft. P & S

3510 net + (2 scarphs) 972 + (1/2 shift) 101 + drop 5041

Naval Timbers - 58 to 68 - 20 pcs.

3930 including scarphs + drop 4323

Floors - 58 to 68 - 5 pcs.

3390 including scarphs + 40% drop 4746

Floors - 12 to 40 - 28 pcs.

9494 including scarphs + 40% drop 13292

Side Frames - 58 to 68 (3 futtochs per frame) - 60 pcs.

7324 including scarphs + 75% drop 12817

Garboard A - 5 to 68 - 157.5 ft. P & S

2835 net + (3 scarphs P & S) 189 + drop 3326

Garboard B - 5 to 68 - 157.5 ft. P & S

2362 net + (3 scarphs P & S) 158 + drop 2272

Plank Sheer - 1 to 68 - 170 ft. P & S

1360 net + drop 1496

SEQUENCE 8

Removals: miscellaneous.

Replacements: 22493 BDF excluding drop.

Naval Timbers - 12 to 46 - 68 pcs.

11397 net + drop 12537

Floors - 5 to 9 - 8 pcs.

1640 including scarph + 40% drop 2296

Sister Frames - 19 to 24 - 10 pcs.

1400 net + 75% drop 2450

Side Frames - 14 to 25 (3 futtochs per frame) - 66 pcs., average 9" length

8056 net + 75% drop 14098

SEQUENCE 9

Replacements: 16507 BDF excluding drop.

Bottom Ceiling Extension - 58 to 68 - 25 ft. P & S

4000 net + (24 scarphs) 2291 + (12 shifts) 1200 + drop 8240

Ceiling - 58 to 68 - 25 ft. P & S

4375 net + (28 scarphs) 1563 + (14 shifts) 1269 + drop 7928

Side Ceiling Extension - 58 to 68 - 25 ft. P & S

1167 net + (8 scarphs) 354 + (4 shifts) 288 + drop 1990

SEQUENCE 10

Replacements: 39148 BDF excluding drop.

Bottom Ceiling Extension - 5 to 54 - 123 ft.

18700 net + (24 scarphs) 2291 + (12 shifts) 1200 + drop 24410

Ceiling - 14 to 54 - 100 ft.

14125 net + (28 scarphs) 1563 + (14 shifts) 1269 + drop 18653

SEQUENCE 11

Replacements: 31465 BDF excluding drop.

Waterway - 12 to 68 - 150 ft. P & S

3687 net + (6 scarphs) 423 + drop 4521

Lockstrake - 12 to 68 - 150 ft. P & S

3540 net + (6 scarphs) 420 + drop 4356

Longitudinal Deck Girder - 9 to 69 - 150 ft. P & S

4170 net + (2 scarphs) 172 + drop 4776

Top Longitudinal Deck Girder - 14 to 69 - 140 ft. P & S

3650 net + (2 scarphs) 182 + drop 4215

Companion Longitudinal Deck Girder - 9 to 69 - 150 ft. P & S

3530 net + (2 scarphs) 146 + drop 4044

Main Deck Planking - 12 to 69 - 143 ft. P & S

11545 net + drop 12700

SEQUENCE 12

Replacements: 30130 BDF, excluding drop

Bottom Planking - 5 to 68 - 150 ft. P & S

17000 net + drop 18700

Bilge Planking - 12 to 68 - 95 ft. P & S

5337 net + drop 5870

Side Planking - 1 to 68 - 110 ft. P & S

2273 net + drop 2500

Sheer Planking - 1 to 68 - 170 ft. P & S

4080 net + drop 4488

Focsle Side Planking - 1 to 8 - 20 ft. P & S

1440 net + drop 1584

Keel Shoe 4" x 12-1/2", oak, extending from frame 1 to 80 with 1285 BDF. Repair will involve 992 BDF.

3.0 FASTENINGS

Structural members that are exclusively attachments, such as knees, stems, sternposts, aprons, etc., are to have fastenings as specified in the Contract Plans. Where such specifications are not given, attachment members shall have one fastening per square foot of surface. Structural members whether or not they are also attachment members such as shelving, lodgers, etc., shall have two fastenings per square foot of surface fastened, where not specified otherwise in the Contract Plans.

All fastening must be driven thoroughly tight. Fasteners which do not comply shall be backed out, and the member refastened.

The exact tally of fastenings for each joint or attachment will be a matter for the shipyard to provide, as required in the "Specifications." Generally, the costs for fastenings will be less than 10% of the constructed timber costs.

Fot the various types of fastenings, these values are offered as best estimates for required material.

Trunnels 1034 BDF, locust wood.

Spikes (nails) 12611 lbs., malleable iron.

Through bolts and blunt bolts (drifts) 50128 lbs., structural steel.

Seam wedges (ceilings) 776 BDF net installed, 1552 gross BDF before tapering.

3.1 Alternative Fastening Materials

It is conceivable that timbers may be reclaimed with the use of saturation solution expoxies or resins. This would be especially useful where the body of the timber is acceptable, but the fastening hole is a cause for rejection. In this case the damaged wood around the fastening would be drilled out, or cored. The core would be replaced by a suitable resin.

This could produce a saving in material, but not in labor since the timber would be removed and replaced. In-situ fastening hole reinforcement would apply to those timbers not scheduled for removal and as such would be a slight additional cost.

4.0 COST BASIS

Estimates for these restoration and repair efforts are made on the basis of removal time, material cost and replacement time. For each major structural system, a breakdown of workhours and material costs are supplied. These are intended to be guidelines and should be used to develop fundamental budget figures to be applied over the years that restoration is expected to extend.

The figures which will be used in the preparation of costs will be applied to the restoration or replacement of quantities in the three (3) combinations described below.

a. Material costs are determined by the boardfeet sum of net replacement, scarph length, shift and drop (or waste).

b. Removal costs are determined by the boardfeet of the net replacement.

c. Replacement costs are determined by the boardfeet of the net replacement, scarph length and shift.

Cost estimates for each major structural system, based upon $40/hour labor costs, are broken down as shown.

4.1 Longitudinals

Keelsons (L-1) nominal moulding and siding 18" x 21"

REMOVAL:	one frame space 2.5 ft. - 80 BDF		
	split and remove timber	1	MD
	pull or burn fastenings (6/FRM)	1	
	handling and cleanup	1/2	
	COSTS $10.50/BDF	2-1/2	MD
	8 HR/FT		
REPLACEMENT:	40 ft. lengths - 1260 BDF		
	drilling and carpentry	6	MD
	handling and rigging	3	
	layout and installation	5	
	scarph cut and fasten	8	
	fastening at 16 frames	12	
	cleanup	2	
	$9.50/BDF	36	MD
	7.2 HR/FT		

TOTAL COST - 15.2 HR/FT

Longitudinals (L-2, L-3) nominal dimensions 13" x 14"

REMOVAL:	one frame spare 2.5 ft. - 38 BDF		
	split and remove timber		1/2 MD
	pull or burn fastenings (4/FRM)		1/2
	handling and cleanup		1/2
	$12.75/BDF		1-1/2 MD
		5.1 HR/FT	
REPLACEMENT:	40 ft. segments - 607 BDF		
	drilling and carpentry		3 MD
	handling and riggins		2
	layout and installation		3
	scarph cut and fasten		4
	fastening at 16 frames		7
	cleanup		2
	$11.00/BDF		21 MD
		4.2 HR/FT	
	TOTAL COST - 9.3 HR/FT		

Floors (T-1) nominal dimensions 10-1/2" x 15-1/2"

REMOVAL:	one floor - 335 BDF		
	split and remove timber	1	MD
	pull or burn fastenings	1/2	
	handling and cleanup	1/2	
	$2.00/BDF	2	MD
	16 HR/FLOOR		
REPLACEMENT	one floor		
	milling and carpentry	2	MD
	handling and rigging	2	
	layout and installation	4	
	fastenings and temporary alignment	3	
	cleanup	2	
	$12.50/BDF	13	MD
	104 HR/FLOOR		
	TOTAL COST - 120 HR/FLOOR		

Naval timbers (T-1) - nominal dimensions 10-1/2" x 15-1/2"

REMOVAL:	naval timbers P & S - 385 BDF		
	split and remove timber	1	MD
	pull fastenings	1/2	
	handling and cleanup	1/2	
	$1.75/BDF	2	MD
	16 HR/TIMBERS		
REPLACEMENT:	naval timbers P & S		
	milling and carpentry	3	MD
	handling and rigging	3	
	layout and installation	4	
	fastenings and temporary alignment	3	
	cleanup	2	
	$12.50/BDF	15	MD
	120 HR/TIMBERS		
	TOTAL COST - 136 HR/TIMBER		

Frame (T-2) nominal dimensions 10-1/2" x 15-1/2"

REMOVAL:	one frame (3 futtochs) P & S - 570 BDF	
	split and remove timber P & S	3 MD
	pull or burn fastenings	1
	handling and cleanup	2
	$3.50/BDF	6 MD
	48 HR/FRAME	

REPLACEMENT:	one frame port and starboard	
	milling and carpentry	5 MD
	handling and rigging	2
	layout and installation	6
	fastenings and temporary alignment	7
	cleanup	2
	$12.35/BDF	22 MD
	176 HR/FRAME	

TOTAL COST - 224 HRS/FRAME P & S

Ceilings (C1, C-2, C-3) nominal dimensions 10" x 14"

REMOVAL:	one frame space 2.5 ft. - 29 BDF		
	split and remove timber		1/4 MD
	pull or burn fastenings		1/4
	handling and cleanup		1/4
	$8/BDF		3/4 MD
		2.4 HR/FT	

REPLACEMENTS:	40 ft. segments - 467 BDF		
	milling and carpentry		3 MD
	handling and rigging		3
	layout and installation		5
	scarph cut and fasten		5
	fastening at 16 frames		10
	cleanup		2
	$19/BDF		28 MD
		5.6 HR/FT	

Garboards (P-1) 6" x 18"

REMOVAL:	one frame space 2.5 ft - 22.5 BDF	
	split and remove timber	1/4 MD
	pull or burn fastenings	1/4
	hanlding and cleanup	1/4
	$10.50/BDF	3/4 MD
		2.4 HR/FT

REPLACEMENTS:	40 ft. segments - 360 BDF	
	milling and carpentry	2 MD
	handling and riggins	3
	layout and installation	3
	scarph cut and fasten	2
	fastening at 16 frames	7
	cleanup	2
	$16.75/BDF	19 MD
		3.8 HR/FT

TOTAL COST - 6.2 HR/FT

Hull Planking (P2 - P3) nominal dimensions 4" x 14"

REMOVAL:	one frame space 2.5 - 11.7 BDF	
	split and remove timber	1/4 MD
	pull or burn fastenings	1/8
	handling and cleanup	1/8
	$13.75/BDF	1/2 MD
	1.6 HR/FT	

REPLACEMENT:	40 ft. segments - 187 BDF	
	staging	1 MD
	milling and carpentry	2
	handling and rigging	2
	layout and installation	2
	butt joint and fasten	2
	fastening at 16 frames	5
	cleanup and caulking	2
	$27.5/BDF	16 MD
	3.2 HR/FT	

TOTAL COST - 4.8 HR/FT

Deck Planking (P-4) dimensions 4" x 4"

REMOVAL:	one deck beam space 4.5' - 6 BDF	
	remove timber	1/8 MD
	pull fastenings	-
	handling and cleanup	1/8
	$13.3/BDF	1/4 MD
	.33 HR/FT	

REPLACEMENT	40 ft. segments - 53.3 BDF	
	milling and carpentry	1/4 MD
	handling	1
	layout and installation	1/2
	butt joint and fasten	1
	fastening at 9 beams	1
	cleanup and caulk	1
	$28.5/BDF	4-3/4 MD
	TOTAL COST - 1.10 HR/FT/PLANK	

A summary of these cost estimates is presented in the following table:

COST BASIS

STRUCTURE	REMOVE		REPLACE	
	$ / BDF	HR / FT	$ / BDF	HR / FT
KEELSONS (L-1)	$10.50	8	$ 9.50	7.2
LONGS (L-2, L-3)	12.75	5.1	11.00	4.2
FLOORS (T-1)	2.00	16/FLR	12.50	104
NAVAL (T-1)	1.75	16/N.T.	12.50	120
FRAME (T-2)	3.50	48/FRM	12.35	176
CEILINGS (C-1, C-2, L-3)	8.00	2.4	19	5.6
GARBOARDS (P1)	10.5	2.4	16.75	3.8
PLANKING (P-2, P-3)	13.75	1.6	27.5	3.2
DECK PLANKING (P-4)	13.30	.33	28.5	.75

5.0 COST ESTIMATES

Each sequence has been compiled to show the man hours required and the material costs. The tabulation is presented below:

Sequence	Time (hours)	Repair Cost	Material Cost
1	3,766	$ 151,090	$ 17,164
2	600	24,000	
3	5,756	230,075	
4	3,750	50,000	28,875
5	10,745	429,708	
6	16,161	671,243	25,000
7	27,255	1,089,493	266,749
8	6,485	259,244	101,798
9	7,845	313,633	63,553
10	18,594	743,812	150,720
11	13,705	548,152	121,143
12	20,720	828,576	115,997
TOTALS	135,382	$5,439,026	$873,835

Based upon yearly funding resources of $700,000 for repair and $200,000 for materials, the projection is a material acquisition within 5 years, and a repair within 8 years. Although funding may change for the better, labor costs will become more expensive. A reasonable expectation for restoration would be 10 years rather than 8. cost would be expected to appreciate accordingly.

SECTION V - RESTORATION LOGISTICS AND REPORTS

1.0 WORK FLOW CHART

The 1980 "Specifications" will require the prime contractor to prepare and submit to NPS at monthly intervals progress schedules. Due to the extended period of time over which restoration will take place, no single contractor will have control over the entire repair other than NPS. In order to maintain repair scheduling and to retain the perspective of the entire work scope, the repair of the major structural systems at their plateaus and sequences is shown as a work flow master plan.

The progress of the restoration is charted to assure material deliveries and funding are available at each sequence or phase. Labor availability will be the responsibility of each repair contractor, but basic man hour requirements are represented.

2.0 RESTORATION PROGRESS PLANNER

The various restoration sequences and plateaus are re-resented first as a general outline of the program and second as definitive drawings. Each representation shows the areas of the vessel to be restored and the boardfeet requirements. The intent is to provide a quick appraisal of each element of the restoration and to allow the progress of the restoration to be easily charted as each element is repaired.

The required work is expressed as boardfeet, frame location and pieces for each structural system. Removals, indicated by a (-) are shown as net boardfeet; that is to say, the extent of damaged timber only. Replacements, indicated by a (+), are shown as actual boardfeet going back in, including the required additional lengths to satisfy scarph and shift specifications.